siphonostelic ferns in which the medullary rays are narrow or lacking. These feature forms are interpreted as an evolutionary series in which the outstanding is the development of a stelar pith by means of a reduction of the central tracheids and their replacement finally by parenchyma. It would be difficult to prove or disprove this view. That a stelar pith might originate in this way or by an expansion of the stele, as in the roots of many of the higher plants, is unquestioned. But that these fossils represented evolutionary stages which culminated in the conversion of a part of a stelar pith into phloem and endodermis, as in *Osmundites skidegatensis* or *Osmunda cinnamomea*, is unsupported by evidence of any kind.

GWYNNE-VAUGHAN and BOWER accept JEFFREY'S hypothesis as to the extrastelar character of the pith in every other family of ferns, but in dealing with the Osmundaceae they cloud the issue by apparently confusing two problems. From a limited series of imperfect fossils they have tried to discover when and how cortical tissues might have been enclosed by the stele. Failing in this, they conclude that they probably could not have been included at all. But neither are we sure when and how that happened in the other families, and a search through the known fossil representatives would probably end as unsatisfactorily as in the case of the Osmundaceae. Research so far has been successful mainly in verifying the theory that the filicinean pith is extrastelar, and with such forms as *Onoclea*, in which the pith consists partly of epidermal tissues and the atmosphere, there is scarcely any escape from accepting it, just as these botanists have done. It is true that the evidence in *Osmunda* is not as striking as in *Onoclea*, but it is quite as striking as in many other forms with extrastelar piths. There are representatives of the Osmundaceae in which the central pith, peripheral pith, internal endodermis, and internal phloem are texturally like those of the outer cortex, inner cortex, external endodermis, and external phloem, and these respectively are continuous at times through leaf or branch gaps. Moreover, there are abundant instances of what in other groups would readily be conceded vestiges of portions of amphiphloic siphonosteles. Applying the same standards of interpretation of anatomical phenomena to all the Filicales, it seems reasonable to maintain that the kind of evidence that has carried conviction in every case but one must hold in all. The question as to when and how the extrastelar pith originated is quite another matter, and I venture to affirm that observations on such features as the relative position of a tracheid and a parenchyma cell in the xylem of a sporeling, or the shape of medullary rays in an adult, will help little in its solution.—J. H. FAULL.

Biology of lichens.—In his culture studies TOBLER[13] used *Cladonia glauca* Floerke and *C. squamosa* (Scop.) Hoffm. By carefully scraping the branches, clusters of soredia were separated. These were sown on sterile

[13] TOBLER, F., Zur Biologie von Flechten und Flechtenpilzen. II. Die Entwicklung der Cladonia-Soredien. Jahrb. Wiss. Bot. **49**:409–417. *pl. 3. figs. 11.* 1911.

earth in flower pots so thickly as to be visible to the eye. The soil was kept from drying by applying distilled water. Cultures of *C. glauca* showed a green growth over the surface of the soil in six or eight weeks. This growth was examined after four months and proved to be a practically pure culture. There was no evidence at this time of development of thallus layers, the structure being gelatinous-granular. The central more moist portion of the culture was green, portions nearer the margin of the pot yellow-white, and the margin white. Microscopic examination showed that the white margin was composed of the lichen hyphae, while other portions of the culture showed the algae present. The thallus layers began to form in six to nine months, the young thalli arising from granules, each of which often arise from two or more soredia. The lichen hyphae were found to become coherent over small areas, and the algae in turn became more deeply seated in the mass. These young squamules were at first few and widely scattered, but later they were seen in large numbers over the surface of the soil.

TOBLER also made a series of cultures on earthen plates. By keeping the air and soil moist in the plate, the hyphae grew luxuriantly. Then he allowed the cultures to dry out for two months. On moistening again, soredia-like masses appeared at certain points over the surface of the soil. Some of these masses were white and composed wholly of lichen hyphae, while others were pale or darker green. These masses increased in size slowly, but did not differentiate into thallus layers.

Hanging-drop cultures were also tried. In three months the soredial masses had grown considerably, and the lichen hyphae were seen radiating beyond the algae in all directions, though the algae had for a time developed more rapidly than the hyphae. Some of the soredia disintegrated and gave rise to many free spherical algae, which he thinks may have passed through a motile condition. Lichen hyphae were seen growing over these algae, but only occasionally attached to them.

The responses to conditions of moisture and light were studied. It was found that soredia from both species would grow luxuriantly after the branches bearing them had been kept in a dry room at about 10° C. for five months. Both the lichen and the algae retained their vitality and grew when moisture was again applied, but the former better than the latter. After cultures had remained in the dark for two or three months, no remains of the algae could be found, while the lichen hyphae had grown well, probably becoming saprophytic on the algae.

TOBLER'S results correspond well with what has been observed in nature, where soredia-like growths are often observed growing about patches of *Cladonia*. Like his cultures, these show in some places a pure white color due to strong development of lichen hyphae, and in other places a light or darker green color, depending upon the number of algae present. The soredia grow slowly both in nature and in cultures. A considerable amount of moisture is necessary for the development of the soredium as a whole, yet the soredium

can endure drying for about a half year at least. The algae endure large amounts of moisture, perhaps better than the lichen hyphae, but the hyphae endure dryness better than the algae. It would add greatly to the value of the research if the cultures could be kept long enough to ascertain the time and conditions necessary for the development of podetia and apothecia.—BRUCE FINK.

Light in relation to tree growth.—A recent bulletin from the Forestry Service, by ZON and GRAVES,[14] will be welcomed by botanists and foresters as a valuable addition to their literature. The authors first show the influence of light on the life of the tree, then discuss the most noteworthy experiments in measuring this influence. The different kinds of light, namely, direct and diffused, and overhead, side, and reflected, are described. Diffused light is the most important, but some plants need direct as well as diffused light, either during their entire life, or at their time of flowering and leafing. An interesting table is given showing the decrease of both direct and diffuse light with increase of latitude, direct light decreasing most, till at the pole it is zero, whereas diffused light is 20. At the equator direct light is 489 as against 227 for diffused light. The rôle of direct and diffused light in trees and forest development, as well as variation of these light quantities with altitude and latitude, is discussed. The minimum light needed for various trees receives attention, considerable data on this topic being cited from WIESNER's well-known researches.

The greater part of the Bulletin is devoted to tolerance, the ability of plants to endure shade. The factors affecting tolerance and the methods of determining it are fully discussed. The results of LUBIMENKO and of GRAFE, dealing with the effect of sensitiveness of the chloroplast and of anatomical structure upon tolerance, are briefly stated. There is also a statement of the influence of climate, altitude, soil moisture, soil fertility, and age, vigor, and origin of the trees upon tolerance. Lists of trees are given showing the order of tolerance as determined by various European and American workers. Finally, the methods of determining tolerance are considered under three heads: (1) empirical methods; density of crown, self-pruning, number of branch orders, natural thinning of stand, conditions of reproduction, relative height, and artificial shading; (2) anatomical and physiological methods; structure of leaves and assimilation capacity of leaves; and (3) physical methods; measurement of luminous light intensity and measurement of chemical light intensity. The authors emphasize the general agreement in order of tolerance of various species as determined by the empirical and by other methods. They also point out the weak points in the various methods. One feels that ZEDERBAUER'S luminous light method is underrated; while WIESNER'S photochemical method, with its evident shortcomings, is over-

[14] ZON, RAPHAEL, and GRAVES, HENRY S., Light in relation to tree growth. U.S. Dept. Agric., Forest Service, Bull. 92. pp. 59. 1911.